September 1972 B72-10278

NASA TECH BRIEF

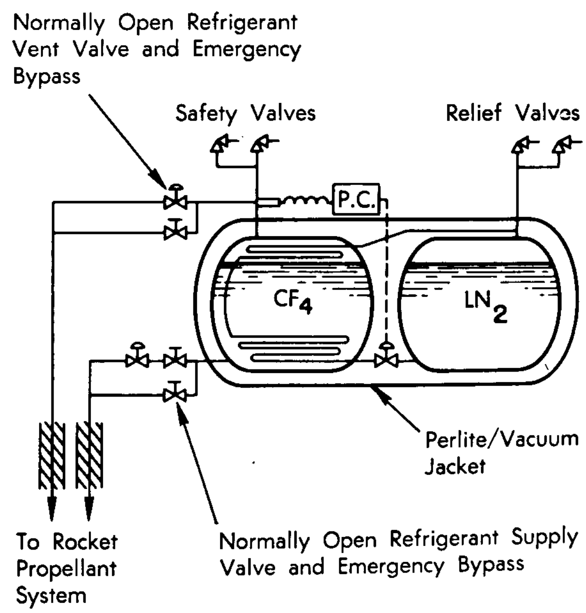
Ames Research Center

Thermal Control for Storage of Cryogenic Propellants in a Multiple-Tank System — A Concept

There are many refrigeration system concepts which can be applied to a ground-hold system for an oxygen difluoride-diborane (OF_2-B_2H_6) propulsion module containing multiple tanks. For example, one concept involves the direct injection of liquid nitrogen or cold gaseous nitrogen into an insulation envelope surrounding the propellant tanks. Oher concepts involve closed-loop systems, electromechanical refrigeration, and ground condensation-and-return of propellant boiloff. If design requirements and objectives are to be met, however, electromechanical refrigeration and propellant boiloff return systems must be dismissed because of their dependence on power sources and because of hazards present in any overly complicated propellant handling system. These shortcomings appear to be absent in the single-pass and closed-loop system concepts.

The single-pass liquid nitrogen system, although appropriate for storage in a common-bulkhead tank, is not suitable for a multiple-tank configuration because of the complexity of the mechanical and thermal systems needed to provide proper distribution of heat input to the liquid nitrogen (LN_2). It is difficult to assure uniform mass temperature of the propellants, and localized subcooling and freezing of the B_2H_6 at LN_2 temperature may result in a serious curtailment of heat transfer. Other refrigerants for single-pass systems have been investigated, but they have been set aside because of cost, toxicity, and reactivity with the propellants. Closed-loop systems have also been examined, but they require a power source to drive the loop; moreover, they are difficult to control and are complex as well as expensive to install and operate.

The proposed design utilizes the advantages of single-loop and closed-loop systems, and employs single-pass LN_2 refrigeration to cool a gravity-fed closed-loop system with Freon-14 used as a secondary



refrigerant. As shown in the diagram, the unit consists essentially of two refrigerant tanks enclosed in an outer vacuum shell insulated with 80-mesh evacuated perlite. The primary refrigerant tank holds LN_2 maintained at 92°K and 310-kN/m^2 (45-psig) by back-pressure relief valves. The secondary tank contains Freon-14 (CF_4) as refrigerant for the heat exchanger coils on installed propulsion module tanks.

In operation, a pressure controller compares the ullage pressure in the Freon tank with the desired

(continued overleaf)

setpoint pressure (temperature), and opens or closes the LN_2 supply valve to the refrigerating coil in the Freon tank to maintain the set vapor pressure. The Freon, maintained at a constant ullage pressure and liquid temperature, is allowed to free-flood the flight refrigeration system, maintaining both propellants at the desired setpoint temperature. Prior to liftoff, the liquid-supply valve to the flight system is closed, allowing the remaining liquid in the flight system to boil off and vent back to the refrigerant storage tank. At liftoff, the refrigeration vent valve is closed, isolating the Freon-14 storage tank. Both flight system lines and ground lines are free to vent to the atmosphere through the liftoff disconnects.

Loss of refrigerant from any cause (line rupture, etc.) would result in a slow rise in propellant temperature and pressure. Assuming 5 cm (2 inches) of foam insulation on a tank of about 0.6 m^3 (25 ft^3) volume, it will require at least 24 hours for OF_2 pressure to rise to 1.0 MN/m^2 (150 psig); hence, with an assumed tank working pressure of 2.8 MN/m^2, a tank pressurization factor of more than 2 for personnel working in the area is provided. An equivalent B_2H_6 tank would require at least 48 hours to rise to the same value. In less than one day, the refrigerant lines can be replaced or a spare thermal control unit can be installed.

The system offers advantages of no propellant loss, small low-pressure lines with nontoxic fluids and simple disconnects, independence from power requirements, fail-safe operation, low operating costs, control by flight or ground system sensing, and control range of 92°K to 156°K (adjustable to freeze B_2H_6 if required).

Notes:

1. The following documentation may be obtained from:

   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)
   Reference:
   NASA CR-109833 (N70-27095), Prelaunch Operations for a Space Storable Propellant Module.

2. See also Tech Briefs B72-10276 and B72-10277.
3. No additional documentation is available. Specific questions, however, may be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: B72-10278

Patent status:

NASA has decided not to apply for a patent.

Source: Gordon R. Stone of
General Dynamics/Convair Division
under contract to
Ames Research Center
(ARC-10560)